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Delivering science and technology to protect our nation and promote world stability

Opportunities and Advancement in LANL Criticality Safety and Research

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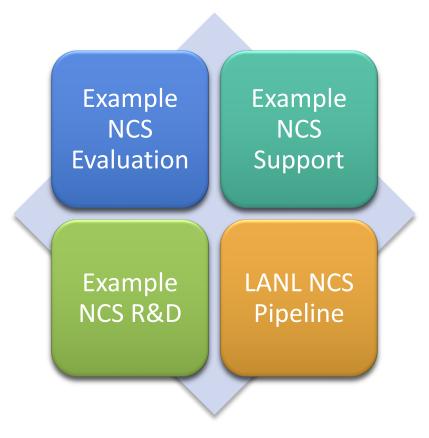
April 2022



ABSTRACT

THE LOS ALAMOS NATIONAL LABORATORY HAS A DYNAMIC CRITICALITY SAFETY PROGRAM RANGING FROM NUCLEAR PHYSICS TO ORGANIZATIONAL PSYCHOLOGY. THIS PRESENTATION TOUCHES ON FOUR ELEMENTS: 1) NUCLEAR OPERATIONS SUPPORT; 2) CRITICALITY R&D; 3) SUPPORT OF NATIONAL SECURITY INTERESTS; 4) UNIVERSITY PIPELINE.

OUTLINE



WHAT IS CRITICALITY

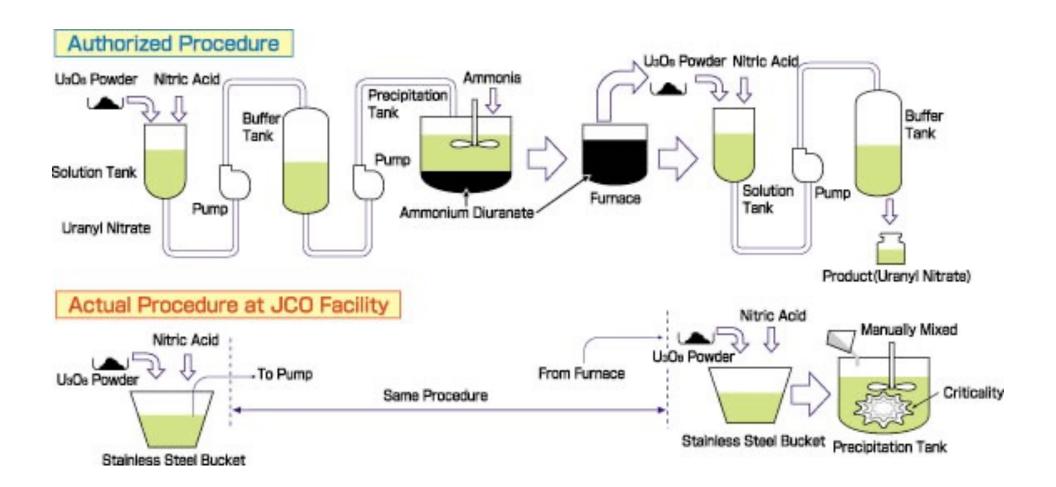
WHAT IS A CRITICALITY ACCIDENT?



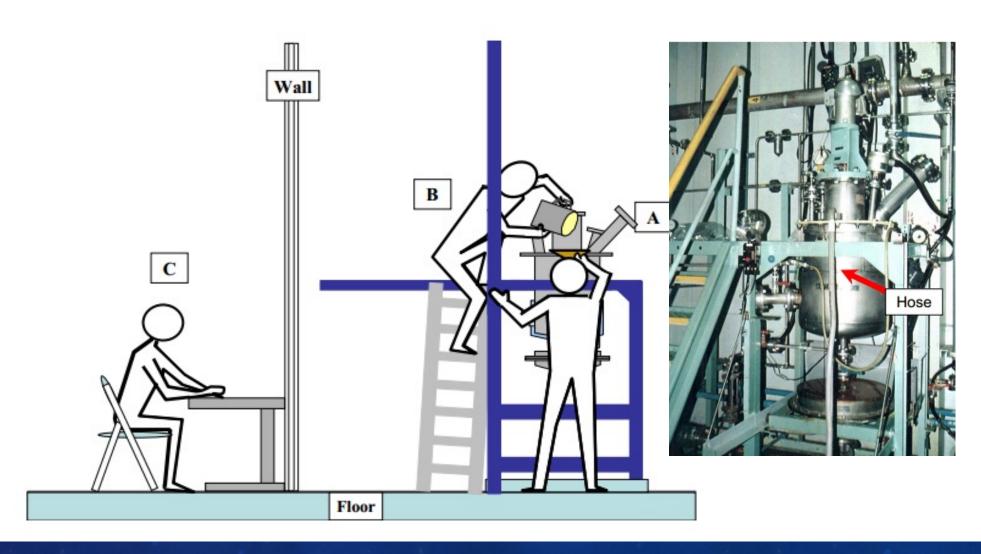


The art and science of mitigating the consequences of self-sustaining neutron chain reaction, preferably by prevention, during the transport, processing, and storage of fissionable materials.

MOST RECENT CRITICALITY ACCIDENT - 1999



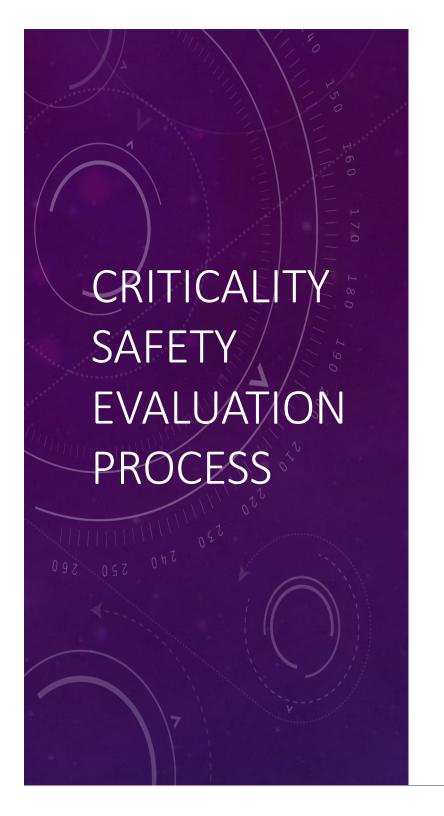
SEPTEMBER 30, 1999 - TOKAI-MURA, JAPAN



NCS EVALUATION OF A FISSIONABLE MATERIAL OPERATION

TEAM BASED APPROACH







Process Description



Normal and **Credible Abnormal Conditions**



Technical Analysis

CRITICALITY SAFETY EVALUATION PROCESS

NCS Requirements/Controls

- Limits on controlled parameters are derived from analysis
- Additional restrictions typically used to make the analysis tractable or in double-contingency arguments

Summary, Conclusion, Appendices

Independent Review for Adequacy

- <u>Intermediate Review</u> of a new, or some/most major revisions
- <u>Independent Review</u> of a DRAFT document that is anticipated to be issued, not required for minor revisions
- Quality Review of a document that is anticipated to be issued
- <u>DC/RO review</u> of the master document

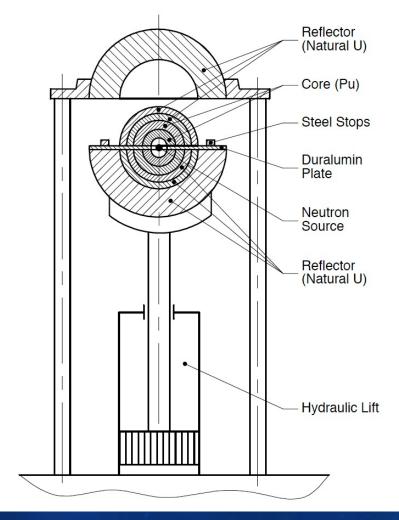
Signatures

AN EVALUATION STARTS WITH A REQUEST

LANL is requested to perform a study of the Sarov accident of April 1953 (accident II-B 5). A plutonium core with natural uranium reflector.

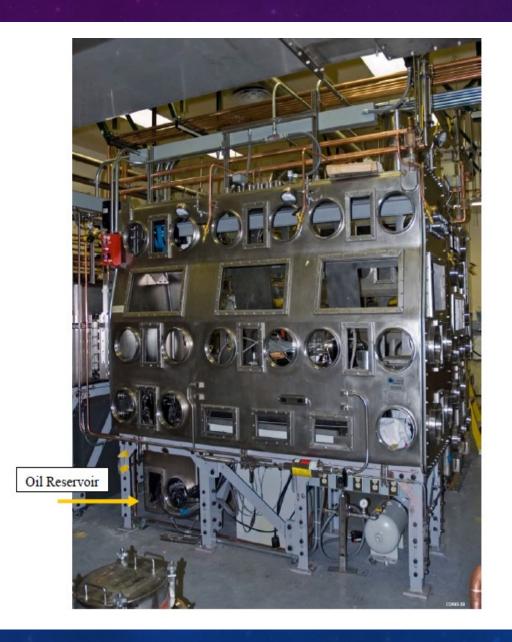
Plan of Action

- 1. Make the pieces.
- 2. Ship the pieces.
- 3. Perform the experiment.
- 4. Report at ANS.
- 5. Submit report to ICSBEP.



GENERAL LOCATION INFORMATION

The evaluation needs to describe the general location of the operation.

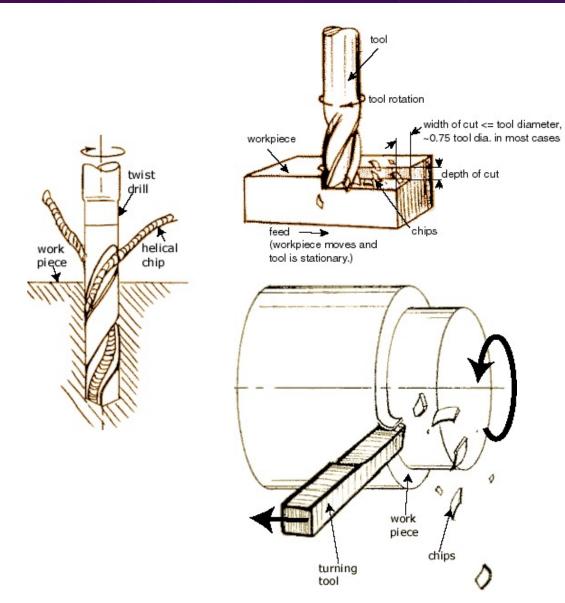


SPECIFIC LOCATION INFORMATION



The evaluation needs to describe location specific information to allow the identification of locationspecific failure modes.

GLOVEBOX OPERATIONS



The evaluation needs to describes the types of activities occurring at the location. This will identify normal and potential failures needing to be addressed.

MISC. ACTIVITIES



Staging

Use of supplies, tools, tooling



Maintenance, Housekeeping, Hold-up Limited quantities of fluid Additional tools, tooling, equipment my be used

PROPOSED NCS REQUIREMENTS

CRITICALITY SAFETY REQUIREMENTS

Administrative Controls

Pu in Metal ≤ 6000 g

Additional Restrictions

- Pieces shall have an inside diameter ≥ 2.0 in.
- Uncontainerized Pu in turnings shall be ≤ 520 g.

NORMAL CONDITIONS

Allowed limit of material

- Essentially un-moderated
- Isolated from nearby operations

Interaction

• 6 inches provides sufficient isolation

Incidental neutron reflection

• 1 inch water reflection on external surfaces bounds reflection considerations

Nuisance spills

- Nature of activity precludes > 2-L
- 2-L of fluid is demonstrated subcritical

MISC. **PROCESS** CONDITIONS

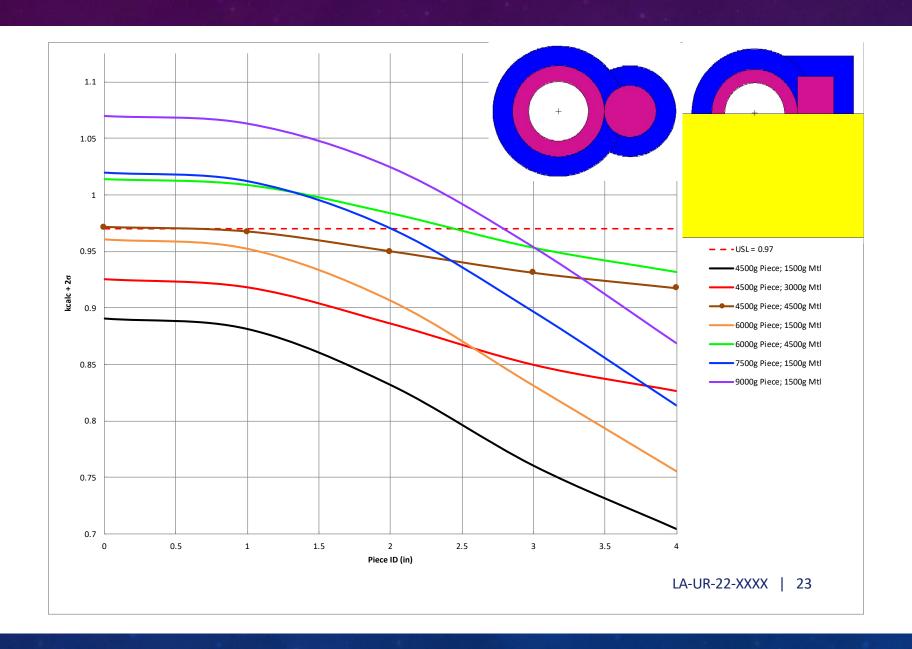
Maintenance, Housekeeping, Hold-up

Gram-level quantities

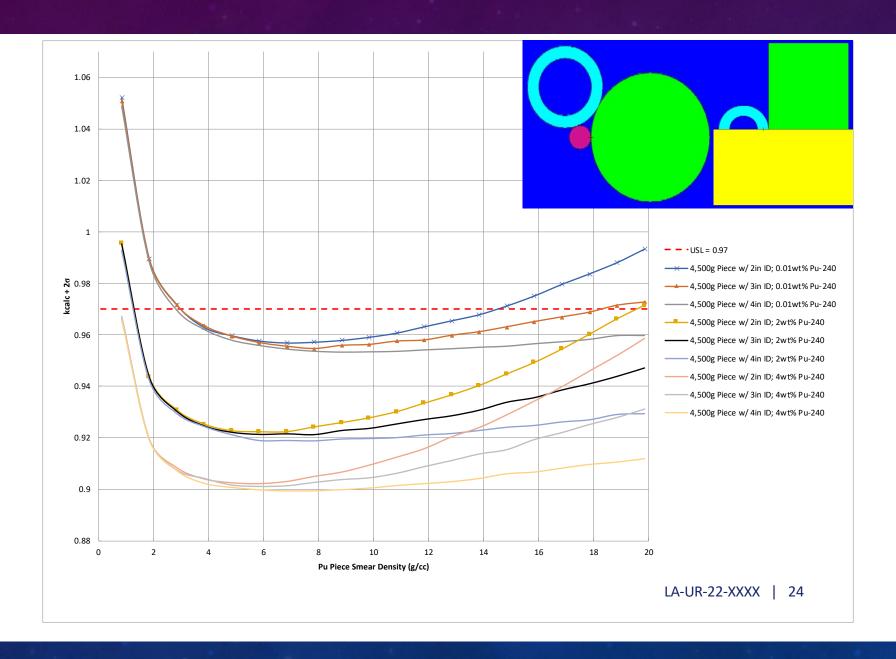
Routine housekeeping

- Considerations of lubrication system
 - QC requirements
 - Nature of activity
 - Location of lubrication system
 - Usage of lubrication system

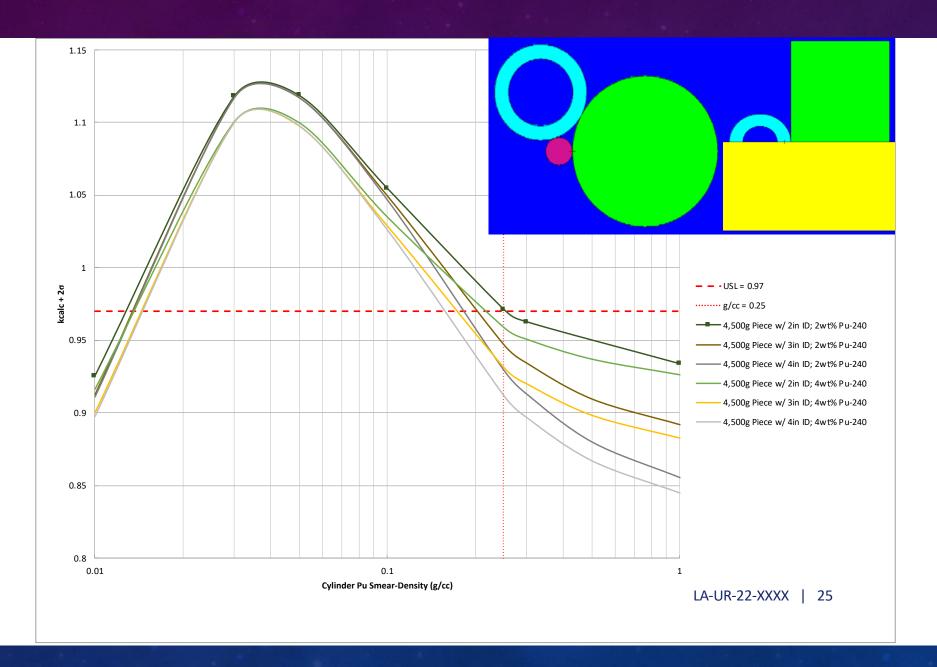
ABNORMAL CONDITIONS RELATED TO MASS



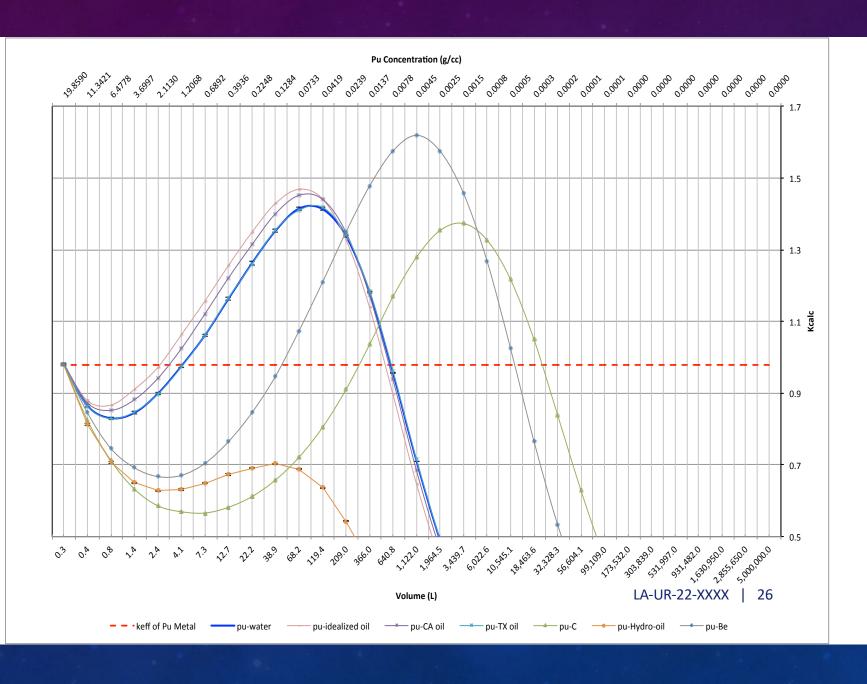
ABNORMAL CONDITIONS WITH WATER



ABNORMAL CONDITIONS WITH WATER



ABNORMAL CONDITIONS WITH OILS



ABNORMAL CONDITIONS RELATED TO GEOMETRY AND SPACING

Piece(s) not satisfying geometry requirement

Operational mishap deforms piece (e.g., drop) Machining mishap deforms a piece (e.g., bad cut)

External event (e.g., seismic)

Loss of Spacing

DESIGN BASIS **EVENTS**

Seismic event with subsequent intro of water

Fire event with subsequent intro of water

- Room fire
- Glovebox fire
- Use of fire fighting agents

FINAL NCS REQUIREMENTS

CRITICALITY SAFETY REQUIREMENTS

Administrative Controls

Pu in Piece ≤ 4500 g

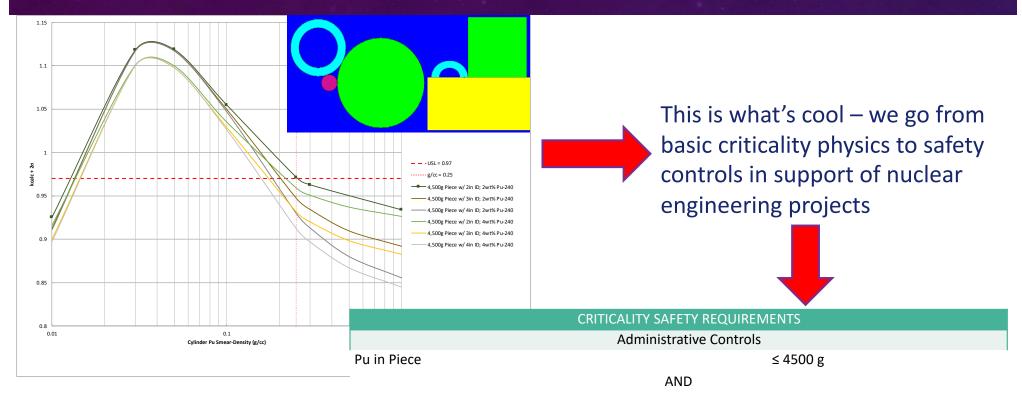
AND

Pu in Metal ≤ 1500 g

Additional Restrictions

- Plutonium isotopic content shall be ≥ 2 weight % Pu-240.
- Plutonium in Piece shall have an inside diameter ≥ 3.0 in.
- Plutonium in Metal shall not be staged within a hemishell.
- Fluids not included in the oil lubrication system shall be limited to ≤2 L.
- Uncontainerized Pu in turnings shall be ≤ 1000 g.
- Containerized Pu in turnings shall be in a Water-Resistant container.

SAFETY CONTROLS ARE DERIVED FROM BASIC PHYSICS AND ENGINEERING PRINCIPLES



Pu in Metal ≤ 1500 g

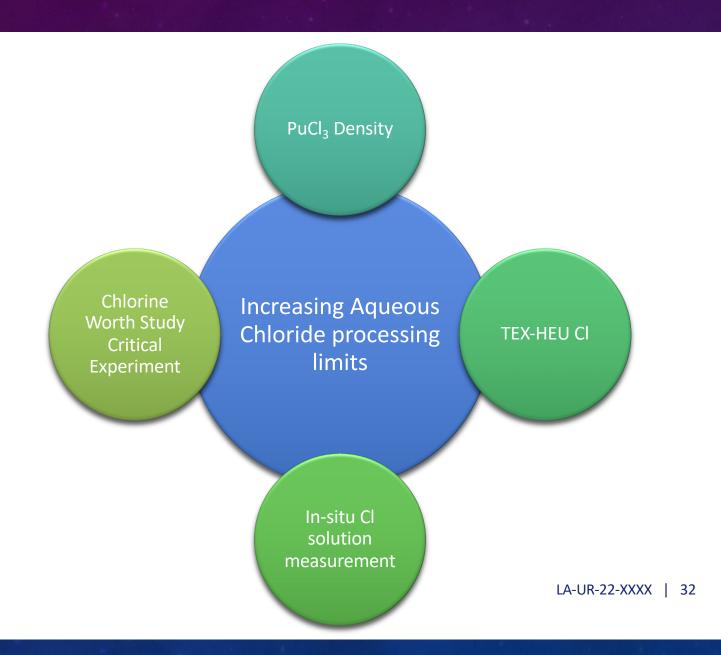
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LANL NCS R&D

THE NEED — INCREASE PROCESSING LIMITS



CHLORINE WORTH STUDY CRITICAL EXPERIMENT

Goal: Measure chlorine nuclear data for use in criticality safety analyses at LANL (focused application)

Lead: Travis Grove and Theresa Cutler, NEN-2

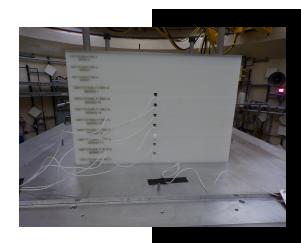
Team: NEN-2, XCP-3, NCS, AMPP-4

Theory: Use Whisper to Design experiment to maximize sensitivity to Chlorine neutron capture in spectra that matches application spectra; incorporate machine learning for efficient design

Execution: December 2021

CHLORINE WORTH STUDY CRITICAL EXPERIMENT







CHLORINE WORTH STUDY CRITICAL EXPERIMENT

Challenges:

Complete benchmark in less than 1 year to submit to ICSBEP TRG in Fall 2022 (very fast timeline)

Data is unusable for NCS until benchmark is approved

TEX-HEU CL

Goal: Measure chlorine nuclear data for use in criticality safety analyses

Lead: Catherine Percher, LLNL

Team: NEN-2 experimenters performing experiment at the Nuclear Criticality Experiment Research Center (NCERC), Nevada Nuclear Security Site (NNSS)

Theory: TEX critical experiment apparatus allows critical data to be taken at thermal and epithermal energy ranges, simulating solution energy ranges

TEX-HEU CHLORINE CRITICAL EXPERIMENT(S)

- Based upon TEX-HEU baseline experiments
- Planned for the future on the Comet assembly machine
- Poly, PVC, and CPVC moderators
- Poly reflector



Partial Stack of TEX-HEU without Reflector



Fully Assembled TEX-HEU Configuration on Comet

TEX CL

Challenges:

Identifying pure/stable Cl source

Optimize TEX-HEU design for anticipated energy spectra (use sensitivity data derived from model of in situ measurement)

Points of Contact:

C. M. Percher, S. S. Kim, D. P. Heinrichs, LLNL

IN-SITU MEASUREMENT

Goal: Use ANSI/ANS-8.6 to take an in-situ measurement of aqueous chloride processing

PuCl₃ density law required to accurately model measurement conditions

Lead: Alicia Salazar-Crockett (NCS)

Team: Theresa Cutler, Jesson Hutchinson, Alex McSpaden (NEN-2)

Theory: Use neutron multiplication measurements to estimate the amount of 'unit' required before the system is critical (subcritical multiplication measurement technique based on ANSI/ANS-8.6)

IN-SITU MEASUREMENT



IN-SITU MEASUREMENT

Challenges: Facility support; overcoming background signal;

DOE Field Office expressed support of the project

References:

W. L. Myers, J. L. Alwin, N. D. Chisler, T. E. Cutler, J. D. Hutchinson, A. Sood, Use of ANSI/ANS 8.6 Standard for Criticality Safety Applications in the Modern World of Advanced Simulation Capabilities, ICNC 2019, Paris, France, 26 August 2019. (LA-UR-19-25398)

PLUTONIUM CHLORIDE DENSITY

Goal: Determine density law for PuCl₃ solution

Required to model data taken from in-situ measurement

Lead: Jennifer Alwin (XCP-3)

Team: Kelly Aldrich, Dung Vu (C-AAC), , Riley Bulso (NCS), Alicia (NCS)

Theory: Isopiestic, Pitzer method for determining density

PLUTONIUM CHLORIDE DENSITY

Challenges:

Validate nitrate data

Emulating French measurement technique

References:

Criticality Calculations Using the Isopiestic Density Law of **Actinide Nitrates**

Determination of fictive binary data for plutonium(IV) nitrate

THE NCS R&D PLAYERS

LANL - NCS Division

- Alicia NCS Team Leader
- Norann Point of Contact for **TEX CI**
- Rilev -Technical Lead for Density Law for PuCl3 solution

LANL – NEN-2

- Travis Grove -Chlorine Worth Study Critical **Experiment** Lead
- Theresa Cutler - In-Situ Measurements Lead
- Dave Hayes, Jesson Hutchinson – Senior Subject Matter expertese

LANL - XCP-3

• Jen Alwin -**MCNP** integration of Cl nuclear data

LANL - C-AAC

• Kelly Aldrich -PuCl₃ Density work POC

LLNL

 Catherine Percher, Chlorine thermal and epithermal nuclear data



ACCIDENT RESPONSE GROUP (ARG) MISSION

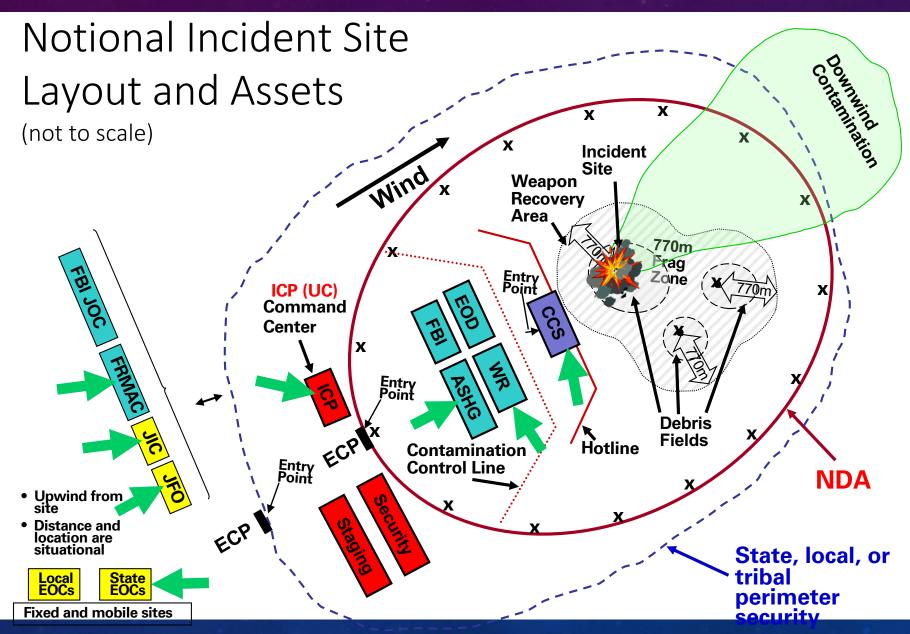
Provide world-wide support to the Department of Defense (DoD) in resolving incidents and accidents involving nuclear weapons or components in DoD custody at the time of the event.

Technical management of the resolution of incidents / accidents involving nuclear weapons / components in Department of Energy custody (when NNSA is the Primary Authority) at the time of the event.





SCALE OF EFFORT DURING AN ARG RESPONSE



JANUARY 1968

- Looked like Lyndon Johnson was ahead in the polls
- Israel expropriated former Jordanian land in East Jerusalem
- England in a serious recession
- AT&T announced the creation of the 9-1-1 system
- Johnny Cash performed in Folsom State Prison
- Green Bay beats Oakland in Superbowl II
- Finale of The Man from U.N.C.L.E
- Red Lobster opens
- Battle of Khe Sanh in Vietnam
- Tet Offensive in Vietnam
- Operation Crosstie (experiment to see if an earthquake can be caused by a nuclear detonation
- Apollo 5 launched for mission to the Moon
 - THEN A PHONE CALL

Los Alamos National Laboratory

B-52 CARRYING 4 NUCLEAR WEAPONS HAS CRASHED....





THULE ACCIDENT – CRESTED ICE RECOVERY PROJECT

January 21, 1968 – B-52 bomber experienced a cabin fire forcing an abandonment of the craft prior to landing

- Six survivors, one fatality
- Carrying four B28FI nuclear weapons
- Conventional explosives detonated and dispersed the nuclear material

January 29 – Public announcement regarding the nuclear components from all 4 weapons being found

- NOTE: No immediate actions were taken
- Time was indeterminate, but it must be done before the ice shelf melted
- Weapon and plane parts put into barrels, cans, drums, and containment vessels

February 20 – Clean up complete

March 30 – Termination of Crested Ice

REMOVAL TECHNIQUES

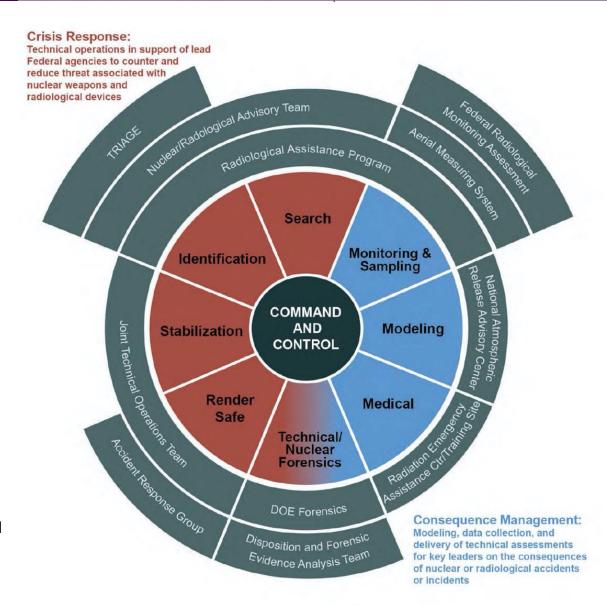
Weapons and Plane Debris

- Put into ~217 drums and vessel
- Each drum and vessel was assayed to obtain an estimated mass value

Contaminated Snow

- 7-ft x 10-ft x 4-ft plywood boxes used to move ~237,000 cubic foot of snow/ice
 - Estimated 3150 +/- 630 gram of plutonium contaminated in the blackened snow
 - An additional 350 g trapped in the ice
- 67 25,000 gallon tanks at the Thule Base to melt the snow/ice

SUPPORT OF WIDER DOE NUCLEAR SECURITY



Taken from FY2018-FY2022 DOE Prevent, Counter, and Respond report

POTENTIAL R&D **EFFORTS**

Technical report for fluids

Technical report for solid pieces

Technical report for contamination

Criticality safety evaluation for potential abnormal weapon conditions

Training module of criticality hazards

Training module for initial response

NCS PIPELINE

COLLABORATION WITH OTHER NATIONAL LABORATORIES







UNIVERSITY PIPELINE

University Pipeline Benefits

The scope of the University Pipeline is to provide students with knowledge of NCS, and to inspire students to pursue a career in NCS after graduation.

Benefit to LANL = reduced training time/cost
Without the pipeline: average qualification time ~ 2-1/2 years
With the pipeline: average qualification time ~ 1-1/2 years or less

LANL NCS Pipeline Participating Universities

Texas A&M University (2017-Present)
University of California-Berkeley (2018-Present)
University of New Mexico (2020-Present)

LANL Results

- ~80 upper level-classmen students have been introduced to NCS
- ~20 students have participated in summer internships
- ~8 summer students offered part-time positions
- ~8 summer interns offered full-time positions as Level 1 CSA trainees
- 4 reached full qualification

LANL NCS PIPELINE **ELEMENTS**

Upper-Level Students

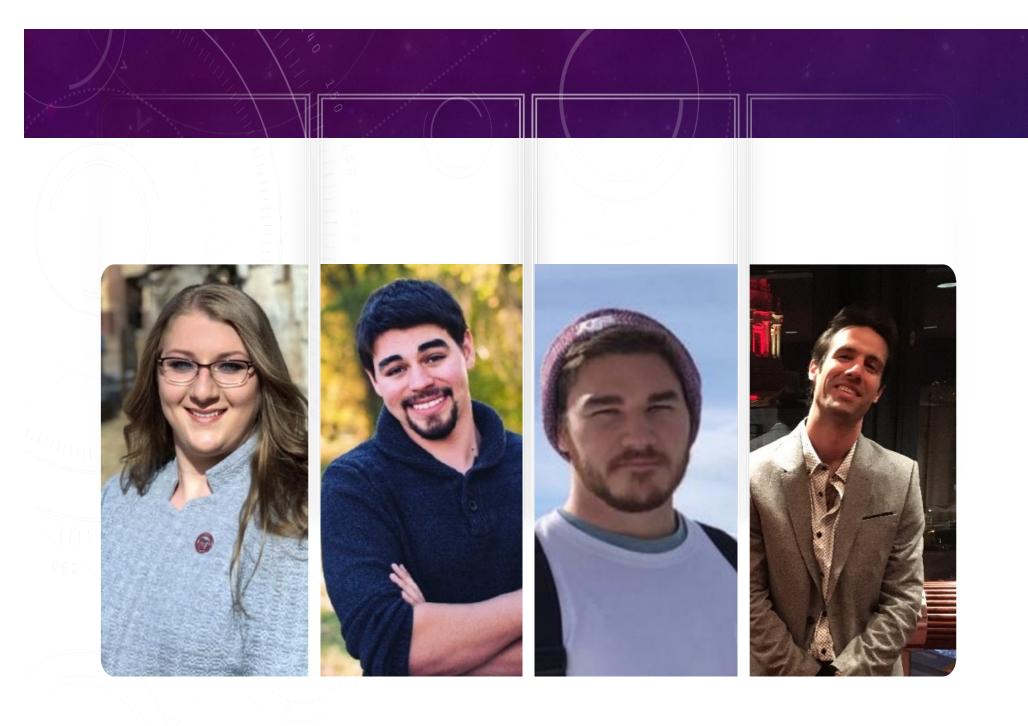
- Bachelor or Masters Degree
- Complete Your Classes

Internship at LANL

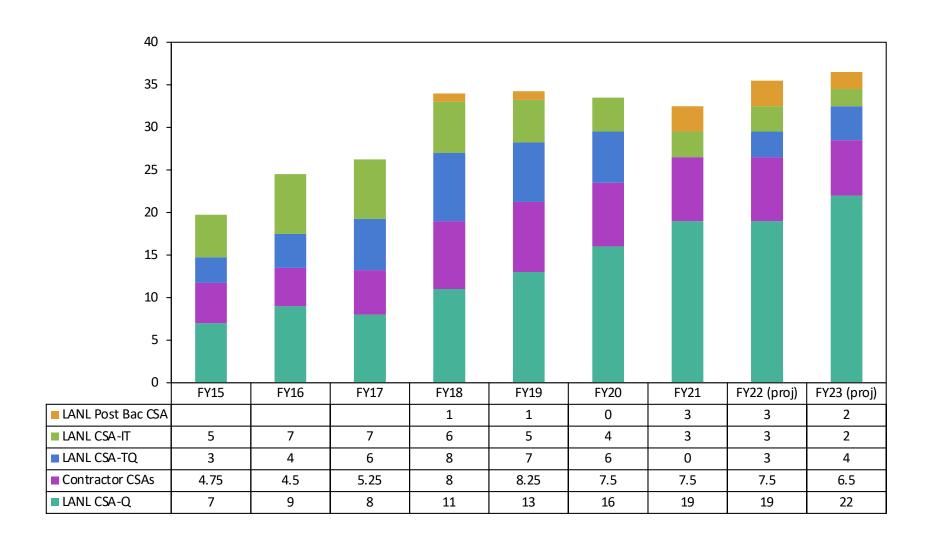
- Summer Internship
- Year-long Internship

Criticality Safety Analyst Staff Position

• Potential to go anywhere in the nuclear engineering discipline



LANL NCS STAFFING



FUTURE PLANS

Continued support of pipeline classes and collaborations

Continued support of internships

Create degree/certificate university program

- Degree/certificate in Nuclear Criticality
 Safety
- Completion of many of the generic NCS qualification requirements

LANL NCS has a future for you

- Operational safety
- Emergency safety
- R&D
- Training

Work with world renowned scientists and engineers

- In the building down the street, or
- In an office just down the hall

Live and play in Northern New Mexico

- Personal life
- Community life
- Outdoor life

CONCLUSION